UNIVERSITI PUTRA MALAYSIA

MECHANICAL PROPERTIES OF OIL PALM (Elaeis guineensis, Jacq.) EMPTY FRUIT BUNCH FIBRE-POLYPROPYLENE COMPOSITES

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MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

1999

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By

LOW AI LEAN

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Forestry
Universiti Putra Malaysia

May 1999

ACKNOWLEDGEMENTS

I would like to express my utmost appreciation and gratitude to my Supervisory Committee, Dr. Jalaluddin Harun (Chairman), Dr. Paridah Md. Tahir, Dr. Khairul Zaman Hj. Mohd. Dahlan and Dr. Mohd. Nor Mohd. Yusoff for their guidance, persistence encouragement and associated aid throughout this study.

Profound gratitude is also extended to Universiti Putra Malaysia (UPM), Malaysia Institute for Nuclear Technology (MINT) and Forest Institute Malaysia (FRIM) in providing the needed facilities and equipment. Additionally, I would like to thank Sabutek (M) Sdn. Bhd., which generously supplied EFB fibres for the study.

Special thanks are also due to Ms. Gloria A. Manarpaac and Ms. Chantara Thevy for their assistance and constructive advice during the experimental work.

Last but by no means least, sincere thanks are dedicated to my dearest parents and Boon Ping, for their constant support and care.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	America Society for Testing and Materials
DMRT	Duncan's Multiple Range Test
EFB	empty fruit bunches
EPC	fibre-plastic composite
FRIM	Forest Institute Malaysia
FTIR	Fourier Transform Infrared
GLM	General Linear Model
IR	infrared
MDF	medium density fibre board
MFI	melt flow index
MINT	Malaysia Institute for Nuclear Technology
MS	Malaysia Standard
OPF	oil palm fronds
OPT	oil palm trunks
PE	polyethylene
POME	palm oil mill effluent
PP	polypropylene
PS	polystyrene
PVC	polyvinyl chloride
SG	specific gravity
TMP	thermomechanical pulping

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science.

MECHANICAL PROPERTIES OF OIL PALM (*Elaeis guineensis*, Jacq.) EMPTY FRUIT BUNCH FIBRE-POLYPROPYLENE COMPOSITES

By

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May 1999

Chairman: Jalaluddin Harun, Ph.D

Faculty: Forestry

This study aimed to evaluate the suitability of oil palm (*Elaeis guineensis,* Jacq.) empty fruit bunch fibres, currently an agriculture waste available in abundance as filler in polypropylenes (PP). The effects of fibre loading, fibre size, type of PP and fibre type were investigated.

Crude EFB fibres were first shredded into shorter lengths (1-3 cm) and thermomechanically defibrillated with the laboratory scale pressurised refiner. The fibres obtained were then screened into three different sizes: Fibres retained on mesh size <0.5 mm, 0.5-1 mm and 1-2 mm. For comparison, crude EFB fibres of same sizes were prepared using the similar process except refining.

The fibres were blended with various types of PP under different fibre loading (20%, 40%, 60% and 80%) by means of Brabender Plasti Corder type PL2000-6. All mixing were done for 30 minutes at temperature of 180^0C and rotor speed of 30 rpm. The compounded samples were then pressed into test samples for various mechanical assessments, namely specific gravity, tensile strength, tensile modulus, flexural strength, flexural modulus, unnotched Izod impact resistance and Rockwell hardness, in accordance with ASTM standards.

The results indicate that fibre loading has significant ($P \leq 0.01$) effect on all the mechanical properties. The specific gravity of samples increased correspondingly with fibre loading, resulted in low specific strength of the samples with high fibre loading (>60%). Tensile strength and unnotched Izod impact resistance of the samples decreased drastically with the adding of fibres. However, tensile modulus and flexural strength of the composites peaked at 40% fibre loading while flexural modulus reached maximum at 60% fibre loading. Fibre size has significant ($P \leq 0.01$) effect on flexural strength, flexural modulus and Rockwell hardness.

Fibre sizes retained on mesh size 1-2 mm and <0.5 mm resulted in better flexural strength compared to 0.5-1 mm. Types of PP significantly influenced all the mechanical properties, except for the blends' specific gravity. The performance of PP14 (PP homopolymer with melt flow index 14), both filled and unfilled, were consistently better than PP6 (PP homopolymer with melt flow index 6) in flexural strength, tensile modulus, flexural modulus and Rockwell hardness. The use of EPC (PP copolymer) has no significant benefits on the blends' properties. Composites of PP and thermomechanically refined EFB fibres were significantly better than those of crude EFB fibres in tensile strength, flexural strength, flexural modulus and unnotched Izod impact resistance.

The results of Fourier Transform Infrared (FTIR) Interferometry scanning clearly indicate that there was no strong chemical bonding between EFB fibres and molten PP. Both components were chemically incompatible to each other.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

SIFAT-SIFAT MEKANIKAL KOMPOSIT GENTIAN TANDAN KELAPA SAWIT (*Elaeis guineensis*, Jacq.)- POLIPROPILENA

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Objektif penyelidikan ini adalah untuk menilai kesesuaian gentian tandan kelapa sawit yang boleh diperolehi dengan kuantiti yang banyak masa kini untuk menghasilkan komposit gentian-plastik. Kesan kandungan dan saiz gentian, jenis polipropilena (PP) and jenis gentian ke atas sifat-sifat mekanikal komposit dikaji secara teliti.

Dalam penyelidikan ini, gentian-gentian kasar daripada tandan kelapa sawit pada mulanya dipotong kepada saiz yang kecil (1-3 cm). Gentian-gentian pendek ini kemudiannya diproses dengan cara pengisaran mekanikal yang diiringi dengan perawatan stim. Gentian-gentian halus yang terhasil ditapis kepada tiga saiz yang berlainan: <0.5 mm, 0.5-1 mm

dan 1-2 mm. Untuk tujuan bandingan, gentian-gentian yang sama saiz tetapi tanpa proses pengisaran juga disediakan.

Gentian-gentian ini kemudiannya diadunkan dengan PP yang berlainan jenis pada kandungan gentian yang berlainan (20%, 40%, 60% dan 80%) dengan menggunakan "Brabender Plasti Corder" jenis PL2000-6. Semua adunan dilakukan selama 30 minit, pada suhu 180^0C dan dengan kelajuan rotor 30 rpm. Sampel-sampel kajian kemudiannya dibentuk daripada adunan-adunan tersebut berdasarkan piawaian ASTM untuk pelbagai ujian mekanikal, seperti ketumpatan bandingan, kekuatan tegangan, modulus tegangan, kekuatan lenturan, modulus lenturan, ketahanan hentaman Izod tanpa lekuk dan kekerasan Rockwell.

Keputusan kajian menunjukan tahap kandungan gentian mempunyai kesan yang signifikan ($P \leq 0.01$) ke atas semua sifat makanikal komposit. Ketumpatan bandingan bagi sampel meningkat seiring dengan tambahan kandungan gentian. Ini mengakibatkan kerendahan dalam sifat-sifat kekuatan tentu bagi adunan-adunan yang mempunyai kandungan gentian yang tinggi. Kekuatan tegangan dan ketahanan hentaman Izod tanpa lekuk menyusut secara mendadak dengan penambahan gentian.

Walaubagaimanapun, modulus tegangan dan kekuatan lenturan bagi komposit memuncak pada kandungan gentian 40% sementara modulus lenturan mencapai maksimum pada kandungan gentian 60%. Saiz gentian mempunyai kesan yang signifikan (P≤0.01) ke atas kekuatan lenturan, modulus lenturan dan kekerasan Rockwell. Saiz gentian 1-2 mm dan <0.5 mm menghasilkan komposit yang mempunyai kekuatan lenturan dan kekerasan Rockwell yang lebih tinggi berbanding dengan saiz 0.5-1 mm. Jenis PP mempunyai kesan yang signifikan (P≤0.01) keatas semua sifat mekanikal, kecuali ketumpatan bandingan. PP14 (homopolimer PP yang mempunyai index lebur galir 14), sama ada dalam keadaan tulin atau adunan mempunyai nilai-nilai yang lebih tinggi dalam modulus tegangan, kekuatan lenturan, modulus lenturan dan kekerasan Rockwell, berbanding dengan PP6 (homopolimer PP yang mempunyai index lebur galir 6) Pengunaan EPC (kopolimer PP) dalam komposit tidak mengakibatkan kelebihan dalam sifat-sifat mekanikal. Komposit yang diperbuat daripada adunan PP dengan gentian-gentian yang melalui proses pengisaran mengakibatkan kelebihan dalam kekuatan tegangan, kekuatan lenturan, modulus lenturan dan ketahan hentaman Izod tanpa lekuk.

Keputusan "Fourier Transform Infra Red (FTIR)" dengan jelasnya menunjukkan tiada ikatan kimia berlaku di antara gentian dengan PP. Ini menunjukkan kedua-dua bahan tersebut tidak berinteraksi di antara satu sama lain dari segi kimia.

CHAPTER I

INTRODUCTION

Background

A fibre composite is broadly defined as a material consisting of a large number of fibres embedded in a continuous phase or matrix, which gives it a definite shape and durable surface (Chum, 1991). In recent years, there has been mounting interest in composite materials in general and fibre-reinforced systems in particular. Their potential in terms of specific strength and stiffness makes them competitive substitutes for solid wood in many traditional applications. In addition, solid wood has two major disadvantages. First, it has poor uniformity. Knots and other flaws produce weaknesses that are difficult to predict. Second, wood is not readily moulded into complex shapes demanded by current manufacturing processes and products. Thus, wood composite provides solution towards these two major discrepancies.

To date, the range of commercial applications for wood composites had been well established since decades ago. Matrices may consist of inorganic glasses or cements, metals and other flow materials. However, in wood based industry, synthetic resins and polymers have the widest uses. With thermosetting resins such as urea and phenol formaldehyde as matrices, the list encompasses plywood, laminated veneer lumber, parallel strand lumber (Parallam), particle boards, flake boards, wafer boards, oriented strand boards, block boards, medium density fiber boards and hardboards. However, with thermoplastic matrix, the use of wood fibres as reinforce filler is a more recent innovation.

Fibre plastic composite (FPC) is generally referred to thermoplastic compositions in which lignocellulosic fibrous reinforcements are imbedded in the thermoplastic matrix. Fibres are introduced into plastics to improve physical properties such as stiffness, impact resistance, flexural and tensile strength (Birley, 1988). Its major uses are found in automobile, construction, packaging, electrical and electronics. Compared to other conventional wood composites, FPC is less popular in industry applications due to the difficulties associated with fibre-matrix interaction (Sanadi *et al.*, 1997). Alumina, calcium carbonate, carbon black, clay, cotton flock, glass fibres, graphite, mica, quartz, talc, wollastonite silicate and wood flour are their more traditional partners (Beck, 1980 and Richardson, 1989). The increasing environmental awareness and the escalating cost of the polymers nevertheless necessitates wider use of lower cost and environmental friendly fillers in these thermoplastics. Among all, the annual-growth lignocellulosic natural fibres (bagasse, kenaf, straw, rice husk, coir, bamboo etc.) are appealing both because of renewable and biodegradable factors (Sanadi *et al.*, 1994b). Their non-abrasive property further enhances their increasing acceptance in plastic industries.

In Malaysia, lignocellulosic fibres are available in abundance, cheap and renewable. Currently, rubberwood (*Hevea brasilliensis*) enjoys overwhelming popularity as the major raw material in the wood composite industry. However, oil palm (*Elaeis guineensis*, Jacq.) fibre, a relatively new source of fibre is predicted as potential substitute that will ease demanding pressure being exerted on rubberwood. Its utilisation in traditional composite panels development such as MDF, particle board and wood-cement boards were found suitable at laboratory scale in many published articles (Chew and Ong, 1987; Mohamad Husin *et al.*, 1987; Rahim Sudin *et al.*, 1987; Chew and Nurulhuda, 1992; Liew and Razali, 1995; Liew, 1996). Palm oil is the main product of oil palm tree. However, oil palm by-products consist of enormous amount of lignocellulosic materials, in the forms of fronds (OPF), trunks (OPT) and empty fruit bunches (EFB). However, EFB has emerged as the most promising one, as it is readily available in abundance at the palm oil mills. The rest require further harvesting processes. Thus, utilisation of EFB in FPC would eliminate costs needed to dispose EFB waste at the mills and generate potential incomes to the industry.

Since lignocellulosic fibre is sensitive to heat, one of the main criteria for selecting thermoplastic for blending with lignocellulosics fibre is its melting temperature. It must melt at or below the degradation point of lignocellulosic components, normally 200-220^{0}C (English *et al.*, 1997). Thermoplastic group that meet the criterion include polypropylene (PP), polystyrene (PS), both low and high-density polyethylene (PE) and polyvinyl chloride (PVC) (English *et al.*, 1997). Nevertheless, PP